Status of the NOνA Experiment

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Abstract. The NOvA experiment has started taking data with the prototype of the near detector placed in a surface building in October 2010. The far detector of the NOνA long baseline experiment is currently under construction and will be located in Ash River, 810 km away from Femilab and 14 mrad off the beam axis. The totally active scintillator detector is designed to identify electron neutrinos that result from the oscillation of beam muon neutrinos. The narrow neutrino beam will be provided by the upgraded NuMI beamline at Fermilab. Among main goals of the NOvA experiment are precise measurement of the values of the atmospheric neutrino oscillations, determining the value of the θ_{13} mixing angle and subsequently the CP violation effect enhanced by the matter effects.

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1. INTRODUCTION

The NuMI Off-Axis ν_e Appearance experiment (NOνA) is a long-baseline neutrino oscillation experiment and the flagship project of the Intensity Frontier initiative of the Fermi National Laboratory. NOνA will study oscillation for the sub-dominant mode of appearance of electron neutrinos in the muon neutrinos beam. NOνA is a next generation neutrino oscillation experiment with a baseline of 810 km and it will utilize the MSW effect of enhancement of neutrino mixing due to they propagation through matter.

The neutrino interactions are detected by both the Near Detector about 1 km downstream of the beam production target and the Far Detector placed 810 km away in Ash River, Minnesota. The detectors are positioned 14 mrad off the NuMI beam axis so that the expected neutrino beam energy spectrum is a narrow band peak at 2 GeV near the $\nu_e \to \nu_\mu$ oscillation maximum. This results with significant reduction of backgrounds in ν_e appearance searches.

The neutrino beam for NOνA experiment will be provided by the NuMI beamline upgraded to 700 kW with 10μs protons pulse every 1.3 s. The planned protons-on-target to be delivered for NOνA experiment during its operation is about 4.9×10^{13} POT/pulse.

The main goal of the NOνA experiment is to measure the oscillation mixing parameter θ_{13} to an order of magnitude better than existing measurements[2, 3]. In Fig. 1a the 2σ sensitivity for measuring the θ_{13} after six year of taking data is shown for upgraded NuMI beam and two possible future upgrades. In Fig 1b the 95% C.L. resolution of the neutrino mass hierarchy in first six year of data taking is presented in the case of the normal hierarchy. In addition precise measurements of oscillation parameters Δm^2_{32} and θ_{23} for both neutrino and antineutrino will be performed. Also NOνA might potentially constrain the neutrino mixing CP violation phase.

2. THE PROTOTYPE DETECTOR

The Near Detector On the Surface (NDOS) is the prototype Near Detector. It is functionally identical to the ND and has been operating on the surface at Fermilab and taking neutrino data since October 2010. The prototype detector was placed in a new building which mimics far detector site construction. The NDOS collects data from neutrino interactions from two beams simultaneously,the NuMI neutrino beam (110 mrad off-axis) and the Booster neutrino beam (on-axis). The prototype detector was useful in testing design of the detectors and check the quality assurance/quality control (QA/QC) at all stages of the production of detector elements and many of installation procedures.

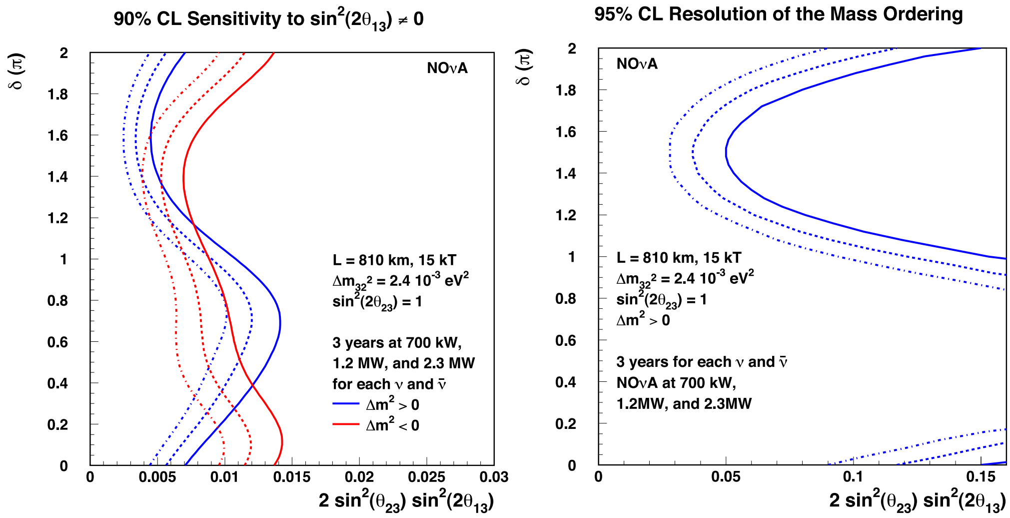

FIGURE 1. Left (a): 2 σ sensitivity of the NOνA experiment to see muon to electron neutrino oscillations. The blue curves assume normal mass hierarchy while the red curves show the inverted hierarchy case. The sensitivity is calculated assuming a 15 kT detector, 10% systematic error on the backgrounds, and 6 years of running split evenly between neutrino and anti-neutrino horn polarities. In addition to the baseline 700 kW beam power ("ANU"), the possibilities using 1.2 MW ("SNuMI") and 2.3 MW ("Project X") are also shown. Right (b): For oscillation parameters to right of these curves, NOvA resolves the neutrino mass hierarchy with better then 95% C.L.

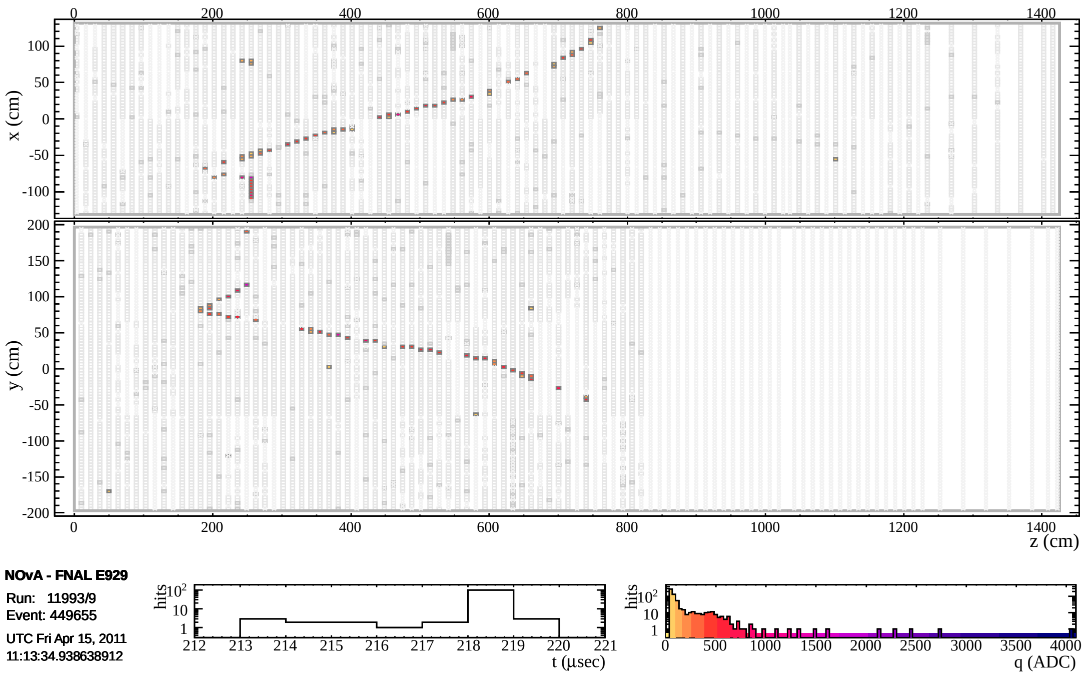

FIGURE 2. A candidate quasielastic ν_μ event observed in the NDOS detector.

TABLE 1. Neutrino interaction data collected in the prototype detector.

Beam	Protons-on-target	Neutrino candidates	Cosmic background
NuMI neutrino	5.6e18	253	39
NuMI antineutrino	8.4e19	1001	69
BNB antineutrino	3.0e19	222	92

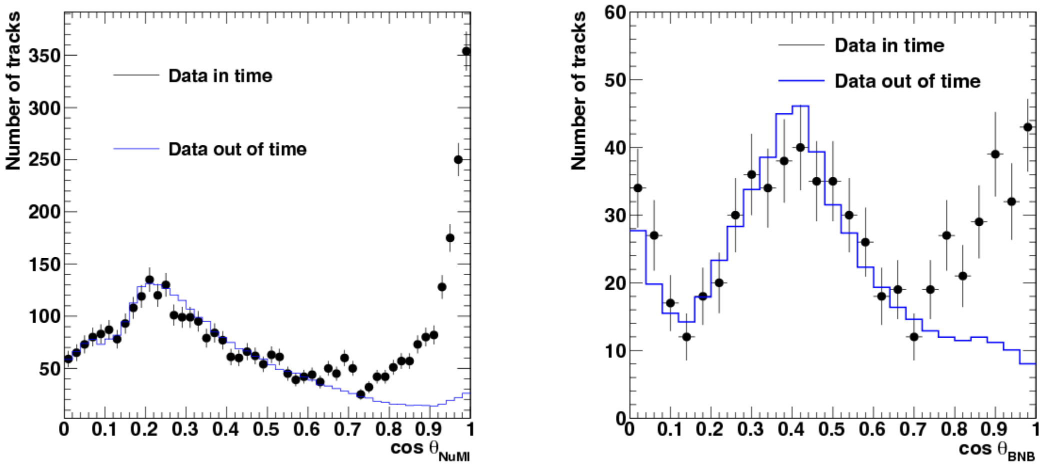

FIGURE 3. Left: The angle between the leading track in the event and the NuMI beam direction (110 mrad upwards along the detector z-axis). These events are selected by applying a basic set of cuts. The event rates are plotted separately for event intime with the 10 usec NuMI spill and the events which occur outside the NuMI spill times. The out of time data has been normalized to the in time data according to the relative sizes of the time windows used to select the events. Right: Angles of leading track in event wrt the Booster neutrino beam direction. Events in time with the Booster spill are shown over a background of out-of-spill events. The background has been scaled according to the relative size of the out-of-time window to the in-time window.

At peak performance, the NDOS was operating with not cooled APDs and with about 75% of its available channels readout including the ones in the Muon Catcher (see Fig. 2). It allowed us to have an early look at real cosmic rays and neutrino interactions. The collected data is sufficient to develop reliable calibration techniques and physics analyses. In table 1. the number of neutrino interaction candidates with estimated cosmic background are shown. Fig. 3 shows the scattering angle for neutrino candidates from NuMI and Booster beams. Clear peaks of the in-time events close to the beam direction show good suppression of cosmic background. The empirical rate of cosmic muons in the prototype detector is about 3-4kHz. That high rate is used for commissioning and stability studies. The cosmic ray reconstructed tracks have been utilised to calibrate corrections for the differences in signal pulse heights from tracks going through cells at different distances from the APD sensors caused by wavelength shifting fibre attenuation.

3. SUMMARY AND OUTLOOK

The prototype detector prepared the NOνA experiment for a full scale production of its two detectors. The NDOS has collected large sample of cosmic muons for calibration and alignment studies and more than 1000 neutrino interactions which will be used to develop physics analyses.

The construction of the far detector will start in the end of 2011 and first detector blocks will start taking data before the NuMI shut-down in March of 2012. At that time the excavation of the near detector caver will start. When the upgraded to 700 kW NuMI beamline will start operating 50% of the far detector will be instrumented and the full 15kT will be complete by the end of 2013.

REFERENCES

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